Superconducting Spoke Cavity Coupler Testing

General Description

Superconducting spoke cavity coupler testing is a program for testing and conditioning the RF couplers that will be used for high power operations in the HINS R&D project. All of the testing and conditioning activities for this program will occur inside of the HINS 325MHz RF Component Test Cage in the Meson Detector Building. The objectives of this program are to ascertain the maximum power that the couplers are capable of transmitting to a RF component during normal operations and to verify the maximum voltage the couplers can withstand before they breakdown in the case of total reflected power. The full reflected power test scenario is important because it simulates a certain condition during normal operations for superconducting cavities when virtually all of the RF power can be reflected back to the couplers. This coupler processing capability is beneficial because it reduces the conditioning time needed in the horizontal test stand and in the cryostat module.

For this test, the Klystron will be used to send RF power to the device under test (DUT). The DUT will consist of a vacuum chamber sandwiched between two couplers, and each coupler has two RF windows. A picture of the DUT has been provided below. The picture shows the DUT on the test stand with the pumps that will be used to keep the DUT under vacuum. More details regarding the DUT's parameters can be found in Timergali's presentation, via the following link: http://tdweb.fnal.gov/HINS/MeetingMinutes/2009/20090122/. RF power will be transmitted from one coupler, through the vacuum chamber, to the second coupler and then to a water-cooled CW RF load of 250KW. This arrangement allows two couplers to be tested simultaneously. The program calls for a minimum of nine high power tests with this configuration. This figure was calculated using an estimate of eighteen cavities and the fact that one coupler is needed per cavity. There is a possibility that more than eighteen couplers will be tested using this program.

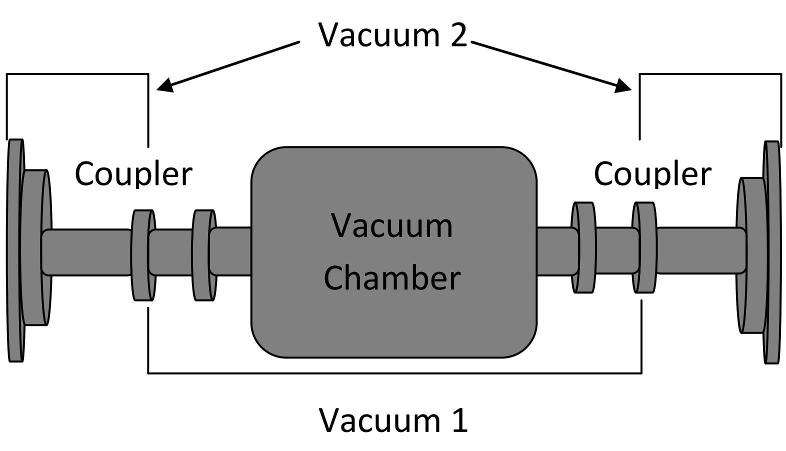

Figure1. Diagram of how vacuum is supplied to the test RF components.

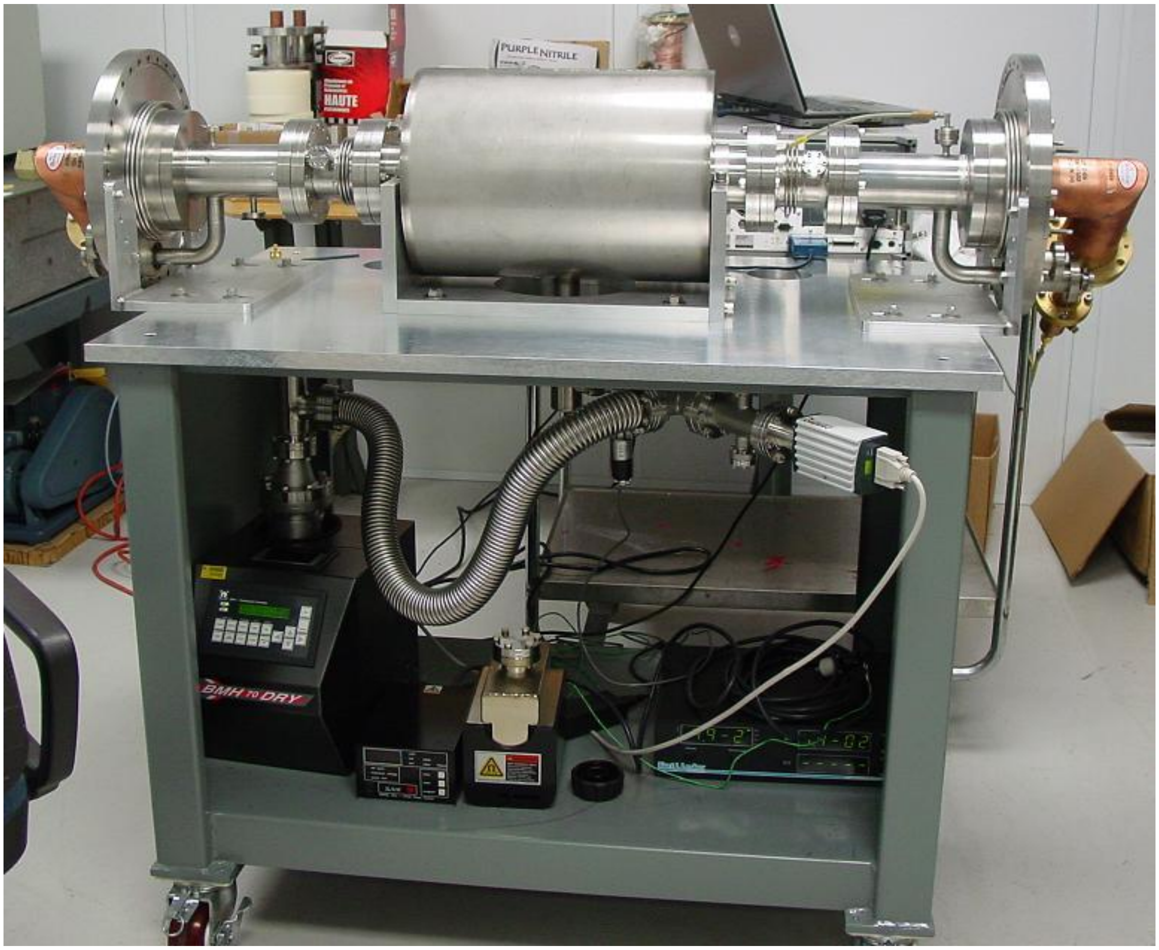

Figure2. The power couplers connected to the vacuum chamber on the test stand.

Special Requirements

A typical condition that may occur during the test is multipacting, which can inhibit the ability to increase the cavity field to desired levels because of power loss and coupler vacuum deterioration. Six field emission probe ports are available on the DUT and each of them will be used to monitor electron activity to observe if multipacting does occur during testing. The temperature of the four RF windows on the DUT will also be monitored using thermocouples in order to detect if any of the RF components are heating up.

Special Hazards/Interlocks

A hazard that arises when working with high power is x-ray generation from high energy electrons. For this particular program, the maximum voltage across the vacuum chamber gap will be 10KV at 1MWatt of power. As a result, x-ray generation will be minimal because the voltage level is too low to reach the higher energies that are associated with x-ray generation.

Another situation that can occur during testing is arcing in the RF windows of the coupler. For this program, the reflected power interlock will be used for arc protection because the design of the couplers does not allow for light detection. The reflected power interlock is currently being provided via Peter Prieto's interlocking system, which will be available for use for this program. In addition, a vacuum interlock will be setup and will indirectly serve as a secondary method against arc protection for the windows of the couplers.

Block Diagram/Layout

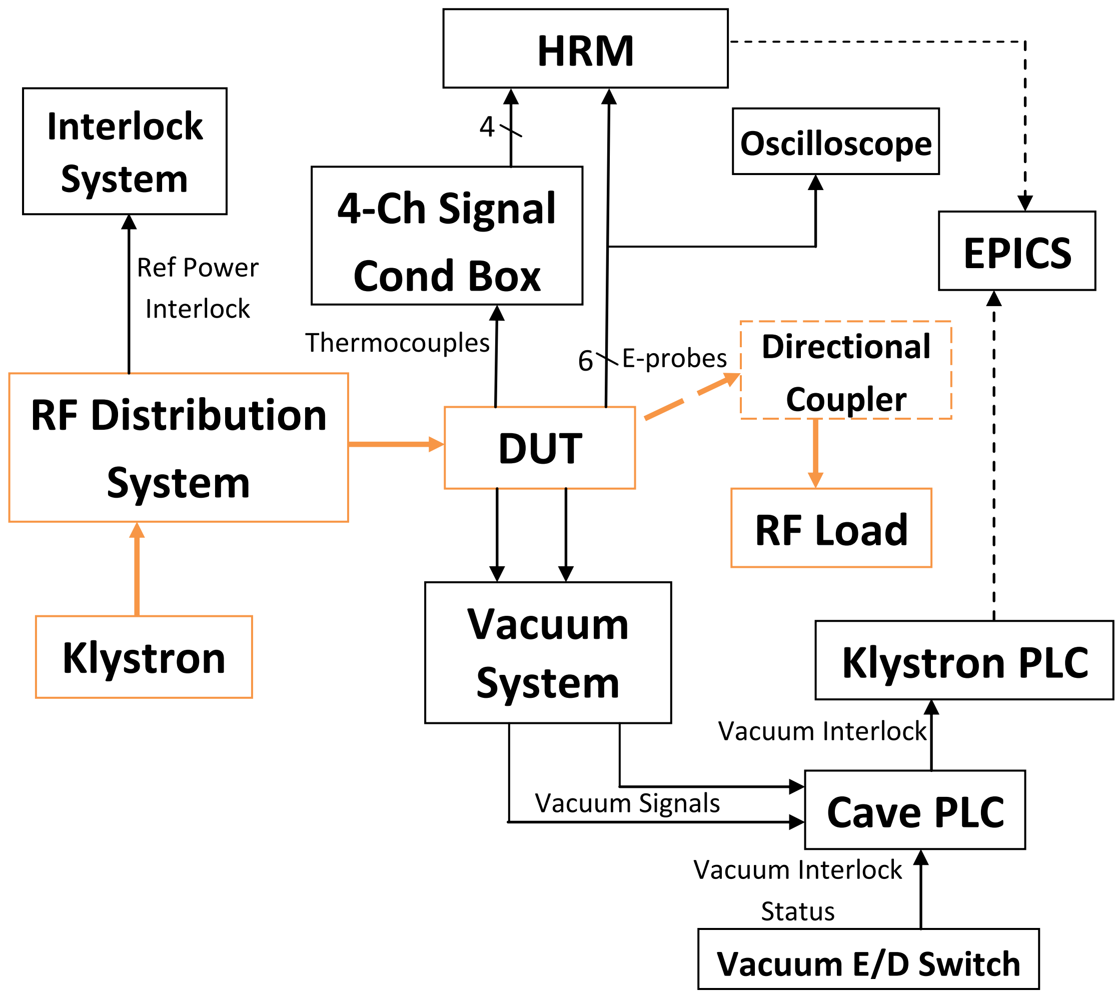

Figure3. Block diagram of connections needed for the coupler tests.

All of the signals in the block diagram above need to be connected as shown to provide read-backs and a vacuum interlock for this test. As mentioned before, the connections for the reflected power interlock already exist. RG-58 cable will be used to make the connections for the six e-probe signals, the four temperature sensors because these signals do not require a fast response. Each of these signals will connect to an A/D channel on the HRM in the Klystron relay racks. This HRM has 16 unused channels that can be dedicated to the read-backs for this test. The e-probe signals will be connected a patch panel on a relay rack before being connected to an A/D channel so that these signals can be split to allow monitoring via an oscilloscope while providing read back functionality as well.

Type J thermocouples will be used for the temperature measurements of the coupler windows because of their accuracy and temperature range. The thermocouples will be taped to the coupler windows for convenience because they will be used for multiple tests. Taping the thermocouples also makes it easier to replace them if they are broken. These are low voltage signals so they need to be amplified before going to an A/D channel. The signal conditioner box will be used to convert and amplify the thermocouple signal to 0-10V analog signal. The box consists of four FC-T1 thermocouple signal conditioners that will be mounted on a DIN rail inside a double-wide NIM chassis. The NIM crate for this box will be mounted inside the relay rack right outside of the test cage.

The vacuum system will be provided and setup by Tom Nicol and consists of a turbo pump, an ion gauge and an ion gauge controller. Two analog outputs from the ion gauge controller will be connected to the Cave PLC inside the relay rack outside of the test cave using RG-174 cable. The vacuum interlock status signal is needed to enable or disable the vacuum interlocking capability for the test cage area so that other tests can be performed in the test cage without the vacuum interlock. This will be a manual toggle switch inside of a NIM chassis and placed in the same NIM crate as the signal conditioner box. The vacuum interlock status signal and the two analog signals from the vacuum controller will be logically combined inside the Cave PLC to produce a vacuum status that will be connected to the Klystron PLC. The Klystron PLC provides the vacuum interlock that is capable of shutting down the Klystron in the event of bad vacuum. The signal from the Cave PLC will be incorporated into the logic used to generate the vacuum interlock so that the vacuum for the DUT is interlocked to the Klystron. Two conductor shielded cable will be used for this PLC to PLC connection. It should be noted that there will not be a need for a dedicated vacuum technician for this program.

The RF distribution system represents all of the RF components used to get the RF power to the DUT, which includes the waveguide coupler upstream of the shutter. This coupler will be used to measure reflected power for this test. The reflected signal from this coupler is connected to the HINS interlock system and is available for monitoring and diagnostic purposes.

The directional coupler before the RF load will be an optional test setup that can be used if there is a desire to measure the total power transmitted through the DUT before the RF load.

Run Plan

This test program will begin in March 2009 at the earliest. The program is expected to last for about 1.5 years, which is dependent on the time it takes to construct all the couplers. All tests will be performed under the guidance and supervision of a HINS operator. Dave Wildman is the lead person responsible for this program.

The procedure for performing the test will be as follows:

- All RF connections and vacuum levels, as well as the RF load water, will be checked to ensure that everything is satisfactory for operations.
- The RF cage will be secured according to the interlock procedures.
- The waveguide shutter will be switched to open and the waveguide switch will be positioned to direct RF energy toward the Cage.
- The vacuum interlock switch will be switched on, which is the enable position.
- Power will be transmitted to the DUT at a low level and a short pulse length initially. The vacuum, temperature and reflected power of the DUT will then be observed to make certain everything is operating properly under various pulse lengths. Only then will the power be increased, and the behavior of the DUT will again be observed at various pulse lengths before proceeding to the next power level. These events will be repeated up to a maximum of 500KW in the traveling wave regime for up to 3ms pulses.
- The same sequence of steps as mentioned above will be performed again, starting at low power and low pulse lengths, for the standing wave regime. For this set of tests the maximum power that will be supplied to the DUT will be 1MW using the 250KW load. Variable shorts will be used instead of the 250KW load for any test that requires more than 1MW of power.

The tests for this program will be executed at a repetition rate of 2.5Hz or less. Measurements will be taken for the vacuum, reflected power, field emissions and temperature of the DUT. Access to the cage will only be needed for setting up RF and signal connections before the testing begins, taking things apart when testing is done and for replacing anything that is broken. For this reason, access to the cage is expected to be minimal.

Contact Information

The following are the key members for this program. Timergali Khabiboulline (ext. 4693) is the requestor of this program and the contact person for more details regarding the DUT and the goals of the test program. Dave Wildman (ext. 4619) is the lead person responsible for assisting with all the tests for this program. His role will consist of operating the Klystron as needed, making sure all safety procedures are followed, connecting any HINS RF components to the DUT and verifying that all signals are at suitable levels to continue operations for the test. Elmie Peoples-Evans (ext. 4055 or ext. 3920) is the program coordinator. Her responsibilities include gathering the resources needed to make all the requested signal connections and verifying that these signals function as desired for the test program. She will also serve as the liaison that communicates all relevant information regarding the program to the HINS management team.

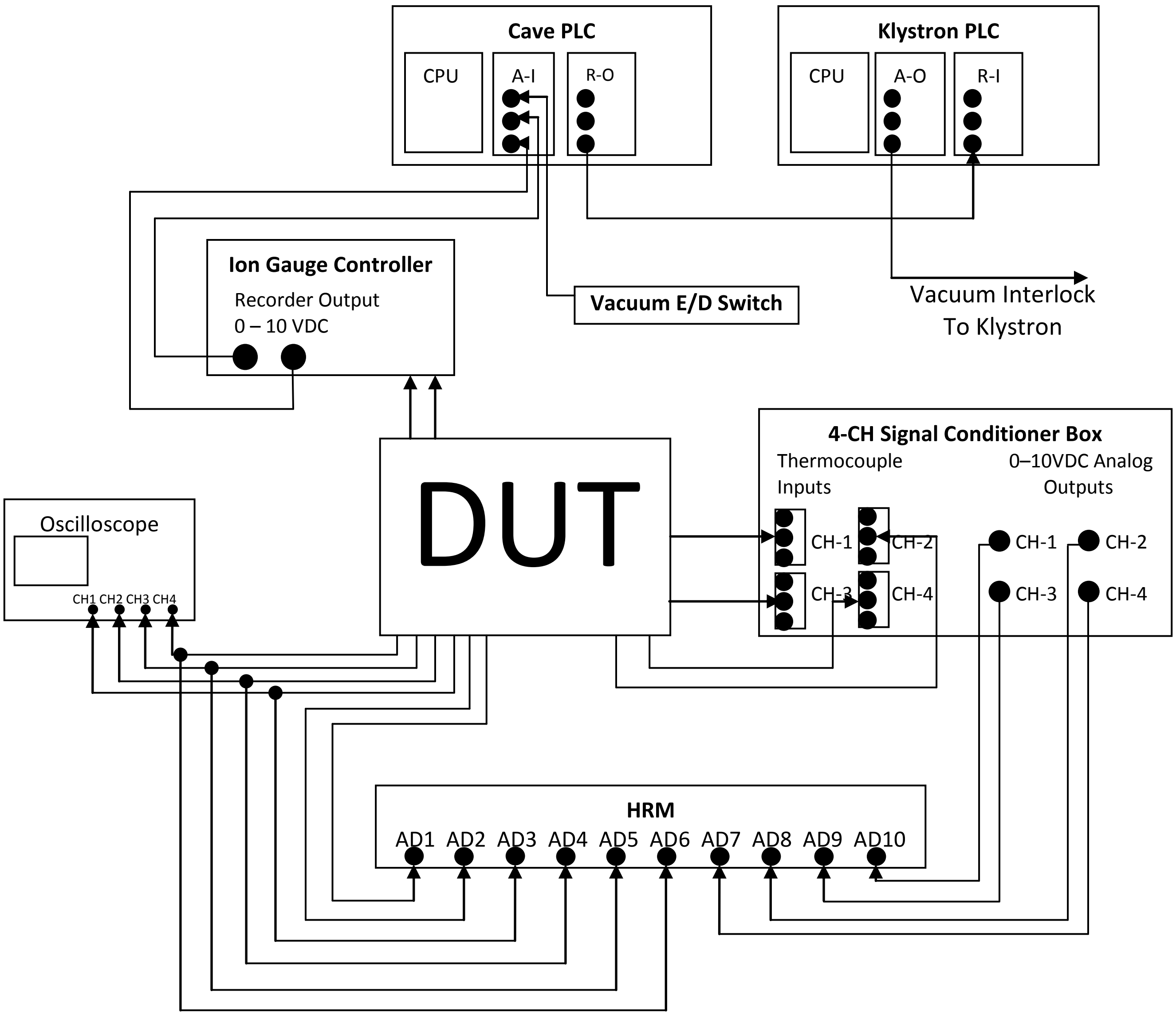

Figure4. Schematic of connections for this test program.